PROCEEDINGS OF SCIENCE

Education & Outreach: some recent successes and the need for community engagement in this activity

David Barney [a,*], Miroslav Myska [b], Connie Potter [a], on behalf of all presenters of E&O activities at ICHEP 2024

aCERN,
EP Department, Geneva, Switzerland
bCzech Technical University,
Prague, Czech Republic
E-mail: David.Barney@cern.ch

Abstract

During the past century particle physics has provided incredible insights into the nature of matter, and the origin and fate of the universe. Theories have been tested and, through an almost-Darwinian process, only those that are substantiated by experiment survive. Along the way, the technological advances made to facilitate our studies have found their way into everyday life for the benefit of mankind, through communication techniques, medical imaging and disease treatment, to name but a few. The present experiments are able to measure phenomena to a precision that was not dreamt of when they began construction, and there are solid plans for continuing the exploration through to the 22nd century, to help answer the many questions that remain and bring further insight into the Universe.

We (the HEP community) are all convinced of the overwhelming benefits our basic research has for humanity. But, as we face increasing challenges for resources, both financial and personnel, as well as environmental concerns for example, for the field to thrive for the next century it is vital to bring the rest of the world with us on our journey. Education and Outreach (E&O) plays a vital role in engaging non-HEP audiences, from school students to educators, to the general public and politicians, in order to gather support for our research and attract young people into fundamental science.

One of the key goals of the E&O activities at ICHEP was to encourage more of our community to take part, to show them how this could be done whilst highlighting the many benefits to the individuals involved. To this aim, three half-day parallel sessions gave the opportunity for 29 people to showcase their new E&O activities and provide information on how these can be re-used and evolved by others. These were complemented by 10 posters and a well-attended Panel Discussion that explored the role that communications, education and outreach needs to play in our field. This latter featured senior physicists as well as professional communicators.

This paper summarises many of the Education & Outreach activities, as well as the Panel Discussion.

42nd International Conference on High Energy Physics (ICHEP2024)
18-24 July 2024
Prague, Czech Republic

*Speaker

PoS(ICHEP2024)040

1. Introduction

Education and Outreach in HEP has certainly grown over the past years. The very first E&O session at an ICHEP was in Melbourne, Australia, in 2012. It coincided with the announcement by the CMS and ATLAS Collaborations of the discovery of the Standard-Model Higgs boson. Outreach efforts from the Collaborations, CERN, other laboratories and institutes, as well as individuals, resulted in an estimated worldwide audience of a billion people. Our research featured on front pages of magazines and newspapers, television and radio news bulletins. People around the world were talking about what we do and, although many of them may not have understood the details, the overwhelming attitude from the non-HEP audiences was "fundamental research is worth doing", validating our efforts. In ICHEP 2012 there was a single 3-hour E&O session that, despite featuring a discussion with the CERN Director General (Prof. Rolf Heuer), was not well attended. E&O was for a few passionate physicists and hired professionals, and not seen as something that should simply be part of what it means to be a physicist.

In the intervening years this attitude has somewhat changed, particularly in some countries where E&O is a serious endeavour, understood to be crucial to the field in general (to gather support, including financial investment) and to our own scientists and engineers. Indeed, in some countries, promotion within the HEP academic structure depends partly on involvement in E&O, whilst in some other countries grants for fundamental research stipulate that a certain fraction must be invested in E&O. These attitudes are not, however, universal in our community. Indeed a common viewpoint, expressed explicitly in the Q&A part of the ICHEP 2024 Outreach Plenary, is "it is a lot of effort to do E&O and a waste of my valuable time, which I could better spend on doing research". It is true that, like any worthwhile endeavour, E&O takes time. And the overall "return on investment" is virtually impossible to measure. Pure numbers of "people reached" is useful, of course. But the intangible side is more difficult: the single person who becomes fascinated by our research at a young age, pursues a career in physics and wins a Nobel Prize; the politician who becomes convinced to invest further in our research; or the member of the public who asks a seemingly innocuous question that makes us scratch our heads and rethink part of our research. What is certain is that doing our research and then not telling the whole world about it would definitely be a waste of time!

There are now so many excellent creative and effective HEP-related E&O activities that building on them, and transforming them to specific requirements, is simpler than ever. Indeed all speakers at the E&O sessions of ICHEP 2024 were encouraged to focus explicitly on how other people could reuse and adapt their activity. There were lively discussions throughout the sessions, and adequate time was allocated for this community engagement.

Going a step further, a Panel Discussion was organized, with senior physicists and professional communicators. This too was meant to engage the community and, judging by the feedback received and the enthusiasm of the audience, achieved its goal.

2. Summary of parallel sessions

Three parallel sessions took place. Each session grouped together related E&O activities where possible. In addition to the normal few minutes for Q&A at the end of each talk, a significant amount of time was allocated at the end of each session for further discussion.

However, such was the engagement of the audience (between 35-60 people in each) that it was more natural to extend the discussions related to each talk.

2.1 E&O Strategy

Several talks focused on the overall E&O strategy for institutes/countries (e.g. IHEP Beijing) and experiments: Dune, Physics Beyond Colliders (at CERN) and the Pierre Auger Observatory. Figure 1 presents some individual slides from the presentations on these topics. There were common threads in these strategic activities, including the benefits of Outreach to:

- Build public appreciation, both at large and in the communities close to the experiment
- Aid financial support e.g. by consolidating support from policy makers
- Inspire young people to pursue STEM topics

Social media now plays a key role in all E&O strategy (see later) but it was interesting to note that traditional printed media still plays an important part, both during specific events for the public (Open Days etc.) and to engage the scientific community directly through partnerships with popular science magazines and scientific journals (example given by IHEP of their partnership with "Modern Physics" journal).

Figure 1: highlights from talks on overall E&O strategy

2.2 Educational activities

Many educational activities were showcased, targeting audiences from 12 years old upwards, focusing on enquiry-based learning and reaching tens of thousands of people. IPPOG (International Particle Physics Outreach Group [1]) has been at the forefront of hands-on studies by older high-school students using data from LEP and LHC experiments and, now, particle-beam therapy. IPPOG "Masterclasses" have, for nearly two decades, shown young people what research is really like, from the data analysis side, collaboration aspects and evaluation of systematic/statistical errors, through local activities complemented by video-linkups between

school groups and laboratories. The relatively small datasets used by IPPOG are complemented by large volumes (hundreds of terabytes) of "Open Data" from the LHC experiments and, more recently, the Pierre Auger Observatory and others. These datasets are accompanied by comprehensive analysis tools and documentation. It was commented that these datasets and tools are actually an excellent way to introduce new physicists to the principles and practicalities of data analysis – so of clear benefit to our own community.

The Pierre Auger data include not only the "physics observables" but also environmental data that are being used by the local community in Malargüe, Argentina to understand weather patterns and climate changes, helping them to plan their local activities.

Peer-teaching was also highlighted as an effective way to engage younger audiences in particular, with PhD students and early post-docs being excellent role models, going into classrooms, exhibitions and science fairs to teach through experiments, data analysis and presentations. Again these highlighted benefits to our own community of being involved in such activities, including:

- Improving presentation skills (crucial in our everyday lives as scientists/engineers)
- Increasing practical skills, especially for those normally involved purely in analysis
- Building confidence and understanding, and gaining perspective into how their specific research fits into the big overall picture of science and society

Some novel approaches to HEP/science education were shown, including a University astronomy class [2] based on a custom-developed science-fiction story. Indeed creative thinking (as will be discussed in the next section too) is one of the key traits of excellent scientists/engineers and developing creative E&O activities allows such thinking to flourish and develop further.

Some special programs were also highlighted, including a US-Ukraine joint venture, the Italian "Inspyre" program and the Czech "Particle Physics Outreach Project". Although some of these activities reach hundreds of students and teachers (and, indirectly, parents, the press and policy makers), others only reach tens of students but the impact on these few is huge and long-lasting.

Apart from the pure research of most educational activities, some audiences benefit enormously from hearing about the spinoff technologies developed through HEP. IPPOG has devoted one part of its extensive portfolio to developing "Witness Stories" [3] to give "concrete examples of successful applications for the benefit of society from (particle) physics and related sciences". Examples include "Accelerators to reduce pollution of maritime traffic" and "Searching for hidden cavities inside the Sun pyramid in Mexico".

2.3 Arts & Science

Part of the definition of "art" is the "expression or application of human creative skill and imagination". One needs look no further than HEP research to see this definition in practice. The sheer audacity of humans to try to uncover the secrets of the Universe by "smashing things together" can only be described as artistic. It is therefore natural that traditional forms of artistic expression work well with HEP research. The ICHEP 2024 venue in Prague showcased, in a special exhibition entitled "BeInspired", beautiful and thought-provoking artworks produced by high-school students to visualise particle physics, whilst a country-wide competition in Italy brought 8000 students together to create science-inspired artworks. At a more 'local' level, which

can be used easily in any exhibition or science fair, "Proton Cookies" have been used to teach and inspire very young audiences. These cookies could be easily extended to neutrons and nuclei etc. The possibilities are numerous, simple and effective!

Examples of successful collaborations between artists and HEP scientists were also shown, including a book of short stories by professional authors working with physicists, and the "Cosmic Piano": a set of five scintillator-based cosmic-ray detectors that each play a different musical note. Between the ICHEP 2024 parallel and plenary sessions this piano was a feature of the "Colours of Ostrava" [4] festival near Prague. The same festival included talks from HEP scientists attending ICHEP, as well as from one of the Panel-Discussion members (see later) and a special presentation from the CERN Director General (Fabiola Gianotti) and Director of International Relations (Charlotte Warakaulle). Figure 2 shows some of the artistic endeavours presented at both ICHEP and Ostrava, including the novel use by Fabiola and Charlotte of their tee shirts to respond to audience questions about HEP!

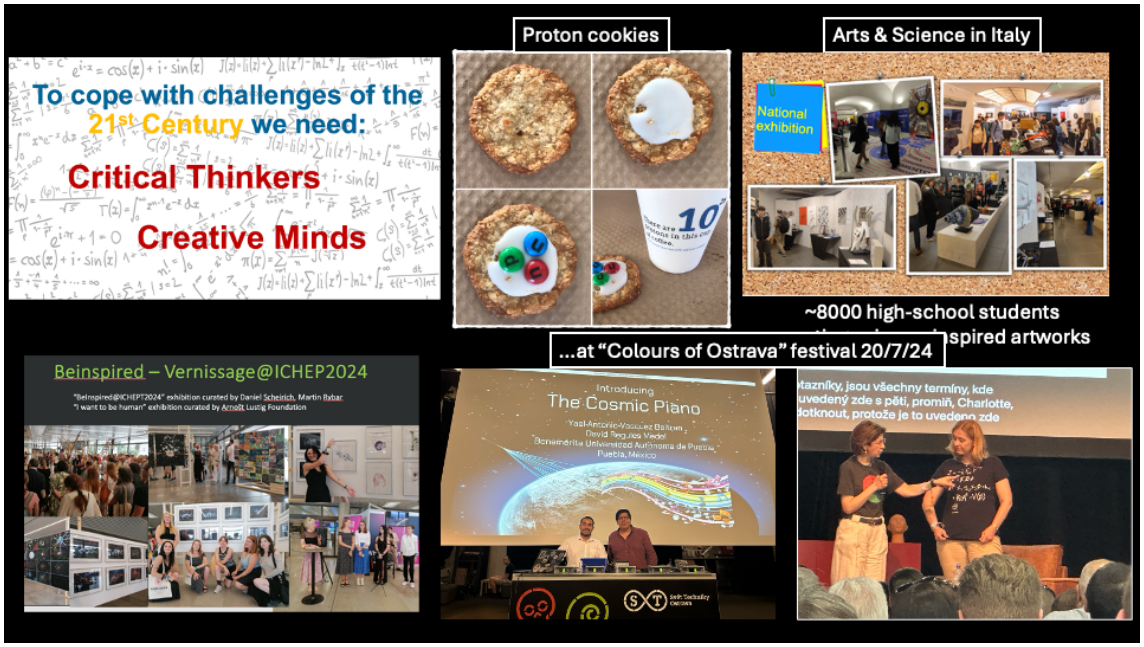

Figure 2: some highlights of artistic projects for HEP E&O purposes

2.4 Games

In a similar manner to which artistic ventures may effectively engage non-scientific audiences, games of all types can attract long-lasting interest and indirect education. Again the variety of activities presented at ICHEP 2024 was huge, ranging from game "workshops" to get young people thinking about how they would develop an HEP-based game, to a collaboration between a professional video-game producer and French particle physicists to produce a 'platform' game based on HEP concepts and personalities. It was interesting to hear the experience of one of the key developers of this video game, that for the target audience it could not be given away for free as its perceived value would be low. Profits from sales of the game will go to develop further levels and further games.

At the other end of the technology spectrum was a complex board game, developed in Czech Republic, based on the whole scientific process – including publication and grant-applications!

Indeed complex board games have a huge worldwide following and engage players for many hours at a time, and then over months and years.

2.5 Exhibitions and visits

HEP exhibitions have existed for decades, mainly hosted by major laboratories such as CERN, FNAL and DESY. These have been complemented by traveling exhibitions and dedicated temporary expositions inside larger more-general venues such as science centres and museums. An ambitious new Italian temporary exhibition decided to focus on Quantum Mechanics, with hands-on activities highlighting paradoxes, complemented by storytelling about quanta, the microcosm and their relation to the macrocosm. Its success – 100000 visitors in 6 months, with excellent feedback – proved that even difficult concepts can intrigue non-expert audiences, who become supporters of our research. Similar concepts have recently been successful in CERN's Science Gateway and, for both the Italian and CERN exhibitions, PhD students and post-docs were employed to make guided tours for schools and the public. This was beneficial to these young researchers as it deepened their knowledge whilst teaching them how to explain their own complex topics in accessible terms.

Dedicated exhibitions are a proven way of bringing non-HEP audiences into our research. Even more powerful are guided tours of our experimental facilities, as presented at ICHEP 2024 by the Italian community involved in the European Researcher's Night: visits to laboratories are incredibly impactful. And, once again, the benefits for the public and the young researchers involved are numerous, including:

- Eliminate stereotypes about the role of researchers in society and about the role of women in STEM
- Promote scientific careers to young people
- Increase trust in research by bringing authentic researchers to the public
- Learn how to communicate and share scientific knowledge effectively and efficiently

And not all visits need to be in person. Indeed only a fraction of those interested in HEP research can possibly visit our facilities physically. But with new affordable technologies we are able to bring people into our environment from the comfort of their own living or class room. Virtual Visits to CMS (and other experiments) have been going on for several years. These are normally hosted by physicists of the same nationality as the audience (as for in-person visits) and include guided tours of the underground facilities (sometimes to places inaccessible to visitors) as well as Q&A sessions. As with most of the activities presented, the talk on Virtual Visits included a part on how others could develop their own VVs simply and in a cost-effective way.

Virtual Reality (VR) is also playing an increasing role for audiences to be able to experience our laboratories and equipment from remote locations. The technologies employed by ATLAS and CMS differ but the effects on audiences are similar: wonder and amazement, with a feeling of really "being there". These were also showcased during the coffee breaks at ICHEP 2024 and those who tried them out were also filled with wonder! Virtual worlds are also finding use in our field amongst engineers and physicists, helping to understand integration aspects of new detectors and also to help with remote repairs/maintenance of equipment. Many people involved in VR for E&O are also developing VR for these other reasons too.

2.6 Social media

Over the past decade social media has revolutionized the way that many people harvest their information. As pointed out explicitly in one talk from the Alice collaboration, almost everyone is now connected to social media, often through a smartphone, attracted by accessible and engaging content. Indeed it is relatively easy to create pages and gather "followers", measuring success through "likes" and re-shares.

However, real success in social media occurs through continued engagement, increasingly difficult in the world of rapid scrolling through countless "reels" and posts. The same strategic planning and implementation employed by other forms of marketing and outreach is therefore necessary. And, like any strategic planning – including for HEP experiments – the first step is to identify the desired outcome and then target the implementation in order to achieve that outcome. Talks at ICHEP focused on these strategic aspects, including the tuning of social-media messages to "please" the algorithms employed by the big platforms in order to reach the desired audiences effectively and attract them to go deeper into HEP through web sites, printed media and exhibitions etc.

Also discussed was a different aspect of the usage of Social Media, from the DESY group: to help, indirectly, with recruitment. Stories on their Instagram channel focus on individuals at the lab: what they do from day to day, how they got there etc. The content provided reaches people considering joining the lab, and feedback from recruits has been very positive.

3. Summary of the Panel Discussion on Outreach

In addition to the parallel talks and associated discussions, a special Panel Discussion took place with, as its headline: "Communication and Outreach – by all of us – is critical for the future of HEP". This took place during a lunchtime, to provide the opportunity for all ICHEP 2024 attendees to participate; not only those that attended the E&O parallel sessions. The reasons for this open discussion were:

- HEP faces enormous challenges that put its future at risk, including:
    - Limited likelihood of major **discoveries** in the coming years (but huge progress in **precision physics**, that may point to deeper understanding)
    - "**Competition**" from other "big science" fields, such as astrophysics, AI, environment science etc.
        - So **can we still attract the best scientists/engineers** into our field?
    - **Cost** of major new collider facility is large in absolute terms (although cost per TeV will be **lower than any present accelerator)**
    - **Environmental impact** of any new collider facility, including electricity needs (but **advances driven by HEP may limit this)**
- It is time not just for a few dedicated individuals in outreach to share our science with the public, but for all of us to realize the importance of sharing our work, why we do it, the ups and downs, the challenges, the excitement, the successes and the failures. We all have to start dedicating some time in some way to communicating with non-HEP audiences, as those involved in the space programmes are obliged to do for example.
- If the community at large does not rise to this challenge, i.e. if we continue "leaving it to somebody else" to do, putting communication and outreach at the bottom of the list of our objectives, the consequences could well be considerable for HEP in the long term.

Five people were invited to participate in the panel:

- Paris Sphicas: senior CERN/Athena physicist and present Chair of ECFA
- Spencer Kelly: UK BBC science/technology journalist
- Sarah Demers: senior Yale physicist and outreach proponent
- Matthew Chalmers: physicist and member of CERN's Communication Group
- Daniel Stach: Czech science/technology journalist

A set of "starter questions" was developed by the discussion moderator (D. Barney), beginning with: "The discovery of the Higgs boson back in 2012 was seen by an estimated worldwide audience of a billion people. Why was this important? What do you think has changed since then in the public's perception of HEP?", and passing through provocative topics including:

- Some people believe that as the Higgs boson is the only new particle to be discovered at the LHC that the past decade has been "a waste of time". How do you respond to such comments?
- Why should "basic research", with no clear application, receive any resources at all?
- How can we keep attracting excellence into our field?
- The audiences who we believe should be interested in what we do are numerous, including politicians & decision makers (the ones with the money!); the media; educators and students (of all ages); general public. Which are the most important audiences to target? Are there other audiences?

The aim of the starter questions was to lead to the main question:

- Many companies and some research institutes employ dedicated PR personnel to do their outreach. In HEP outreach is sometimes seen as an activity for retired personnel, not at all important to our field, or something people 'shouldn't be wasting their time on'. Why should active physicists and engineers be doing any sort of outreach?

In fact most of the intermediate starter questions were not needed as the audience questions/comments to the panel naturally led to the main question! Indeed the audience was larger than anticipated, at around 150 people, and the allocated time of one hour quickly overran by half an hour due to the interest from the audience. The discussion was lively, with the audience raising many issues and questions, sometimes for and sometimes against physicist/engineer involvement in outreach. The different perspectives brought by the panel were complementary and thought-provoking, with even the panel members commenting afterwards that they all learned different things and have a better appreciation of the overall HEP outreach landscape. Figure 3 shows a couple of photos from the session together with some of the salient points raised, whilst Figure 4 highlights some of the quotes from the panel members. Recordings of the complete discussion, and the concluding remarks, are available at [5] and [6] respectively.

A second Panel Discussion at ICHEP 2024, focusing on Future HEP Facilities [7] and featuring directors from major HEP labs, also highlighted the need for excellent Education and Outreach, with some extracted quotations given in Figure 5.

Figure 3: highlights from the Panel Discussion on Outreach

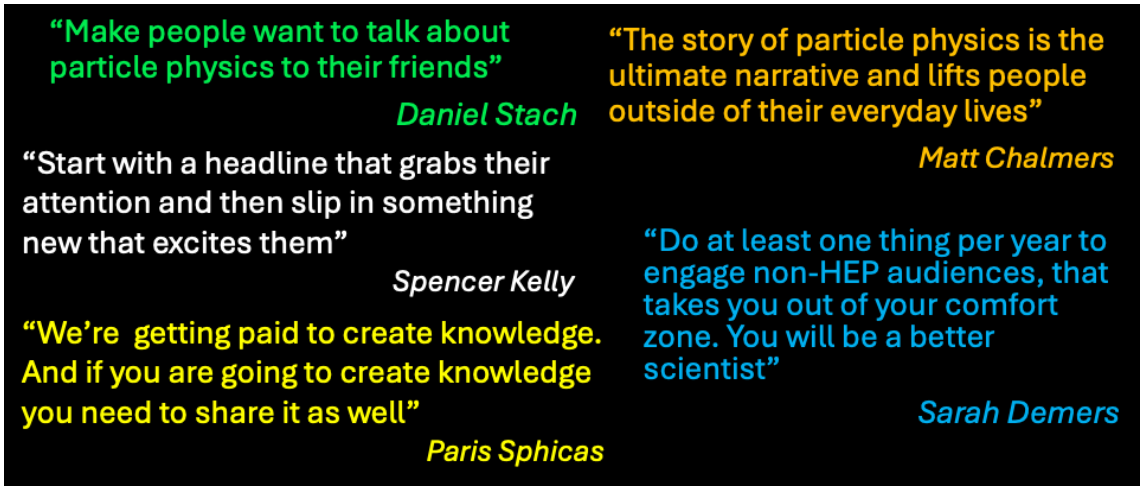

Figure 4: Some quotes from the Panel members

Figure 5: Some comments from the Panel Discussion on Future HEP Facilities

4. Benefits to HEP researchers from involvement in E&O

A major theme occurred throughout the parallel talks, the posters and the Panel Discussion: that although involvement in E&O takes time and effort, it brings direct benefits to the participants, including:

- Improving creative thinking
- Better understanding of the "big pictures" of HEP (physics, detectors, past & future)
- Better appreciation of the whole HEP landscape
- Helps physicists/engineers explain more clearly their own research

i.e. the "return on investment" outweighs the costs.

5. Concluding remarks

To help overcome the challenges faced by our field in the coming decades, communication from **everyone** involved in HEP, and at all levels, will be critical. This cannot be left to a handful of dedicated "outreach activists!" At the same time, it is crucial to emphasize that the skills obtained from being involved in Education & Outreach are extremely valuable for our research as scientists and engineers. And, as such, E&O activities must be encouraged, supported and acknowledged appropriately at all levels, including funding agencies, HEP departments and supervisors.

And there are E&O activities suitable for everyone, whether they wish to write, speak to the public, develop artworks or games, lead Masterclasses etc. Get involved!

References

[1] The International Particle Physics Outreach Group, IPPOG: https://ippog.org

[2] Learning Astronomy through an immersive science fiction experience, Sean Lindsay, University of Tennessee: https://sites.google.com/utk.edu/astronomy490utk/home

[3] IPPOG "Witness Stories": Applications of basic HEP research: https://ippog.org/ippog_witness_stories

[4] "Colours of Ostrava" festival 2024, Czech Republic: https://www.colours.cz/about-festival

[5] Full recording of Outreach Panel Discussion: https://www.youtube.com/watch?v=qOOpT78RR4M

[6] Concluding remarks from Outreach Panel Discussion: https://www.youtube.com/watch?v=NWmAumyldjM

[7] Panel discussion on Future Facilities: https://youtu.be/PY_HwYd65IY?si=fDAuNVn4sfixY14P

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